Climate, Weather, and Water Science

Kristen Averyt
Brad Udall

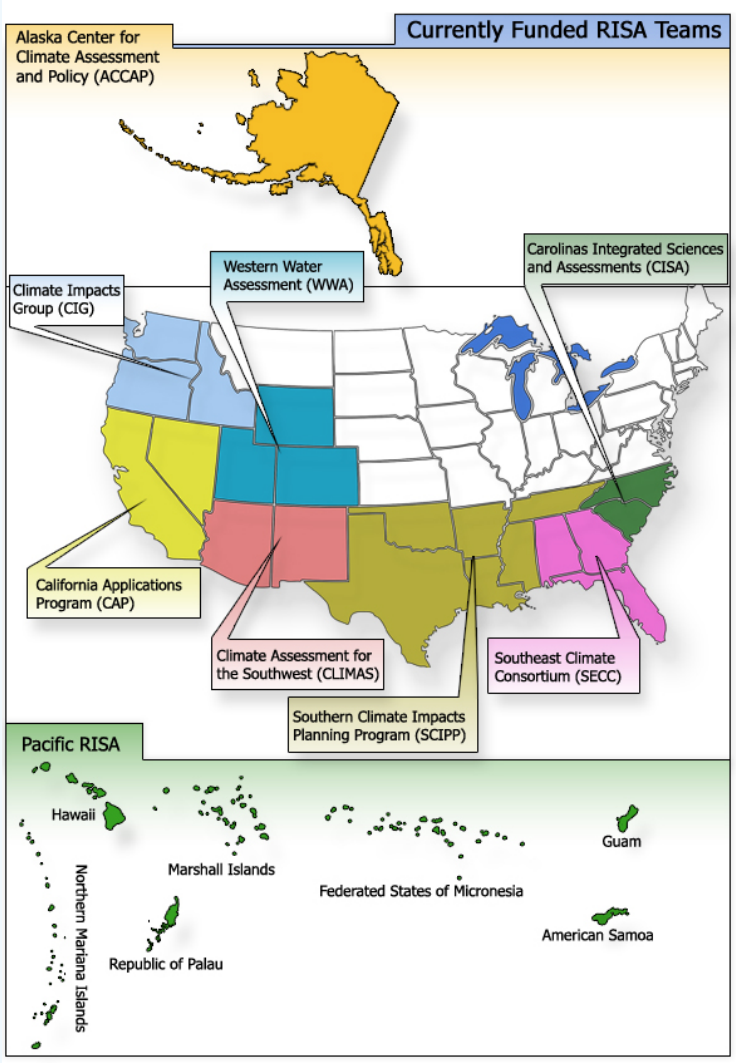
Western Water Assessment

Western Water Assessment

- NOAA Regional Integrated Sciences & Assessments (RISA) Program
- Connect climate research with decision making
- Established 1998, Recompeted 2009

WWA MISSION

"To identify and characterize regional vulnerabilities to, and impacts of, climate variability and change, and to develop information, products, and processes that assist decision-makers throughout Colorado, Utah, and Wyoming."



Western Water Assessment

- NOAA Regional Integrated Sciences & Assessments (RISA) Program
- Connect climate research with decision making
- Established 1998, Recompeted 2009

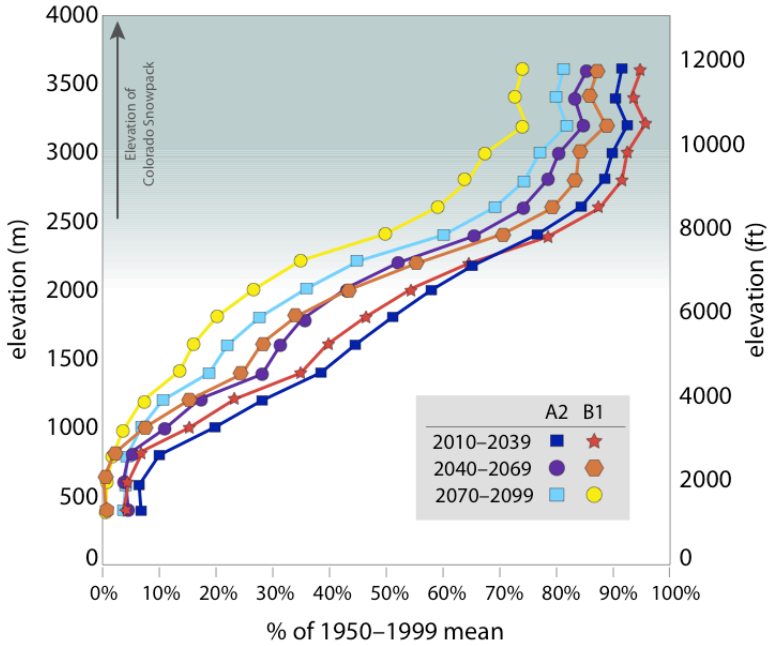
WWA MISSION

"To identify and characterize regional vulnerabilities to, and impacts of, climate variability and change, and to develop information, products, and processes that assist decision-makers throughout Colorado, Utah, and Wyoming."

Climate Change in the West

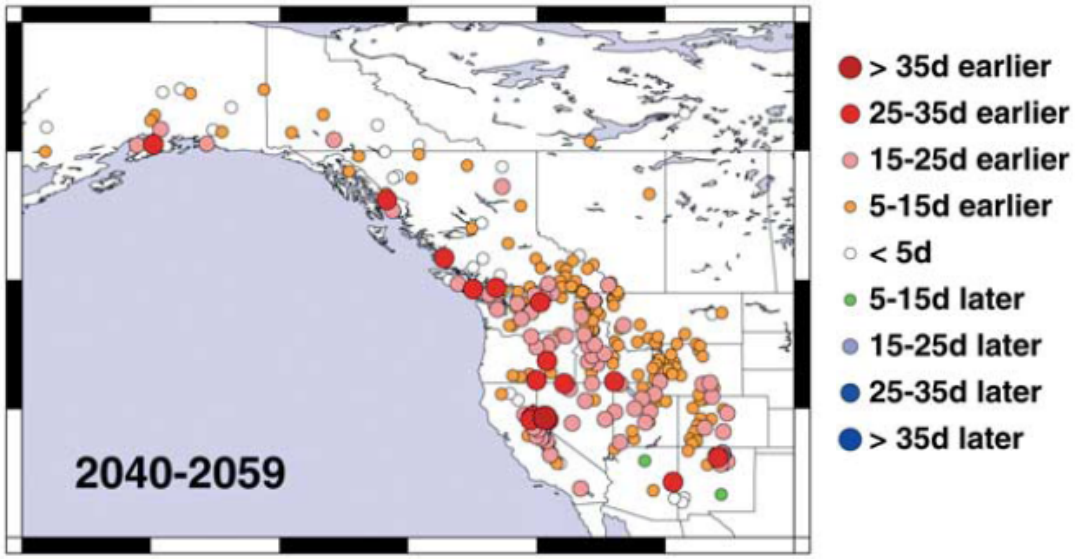
In the Intermountain West, many impacts of climate change will be delivered through changes in the nature of water resources

Projected declines in snowpack



CO Climate Report 2008;
Redrawn from Christensen & Lettenmeier 2007

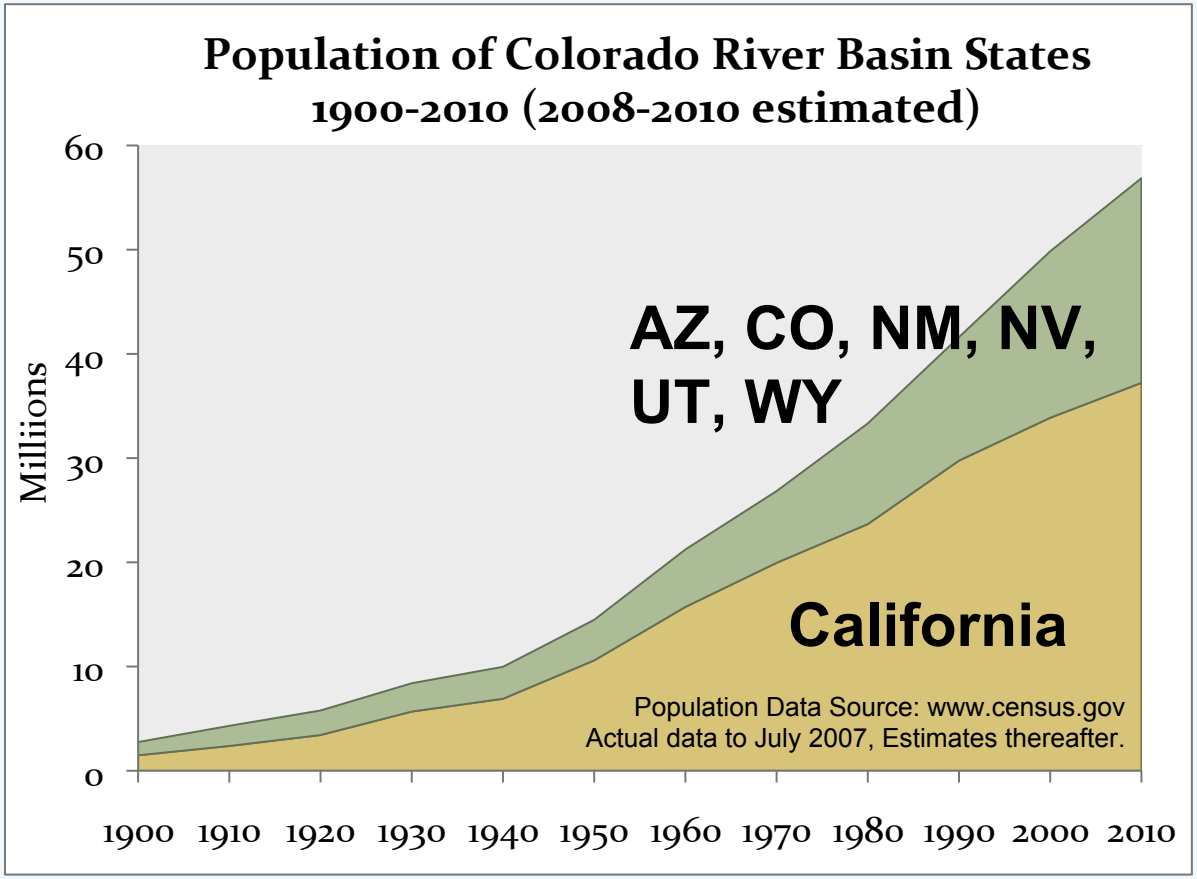
Projected earlier peak streamflow timing



Stewart et al. 2004

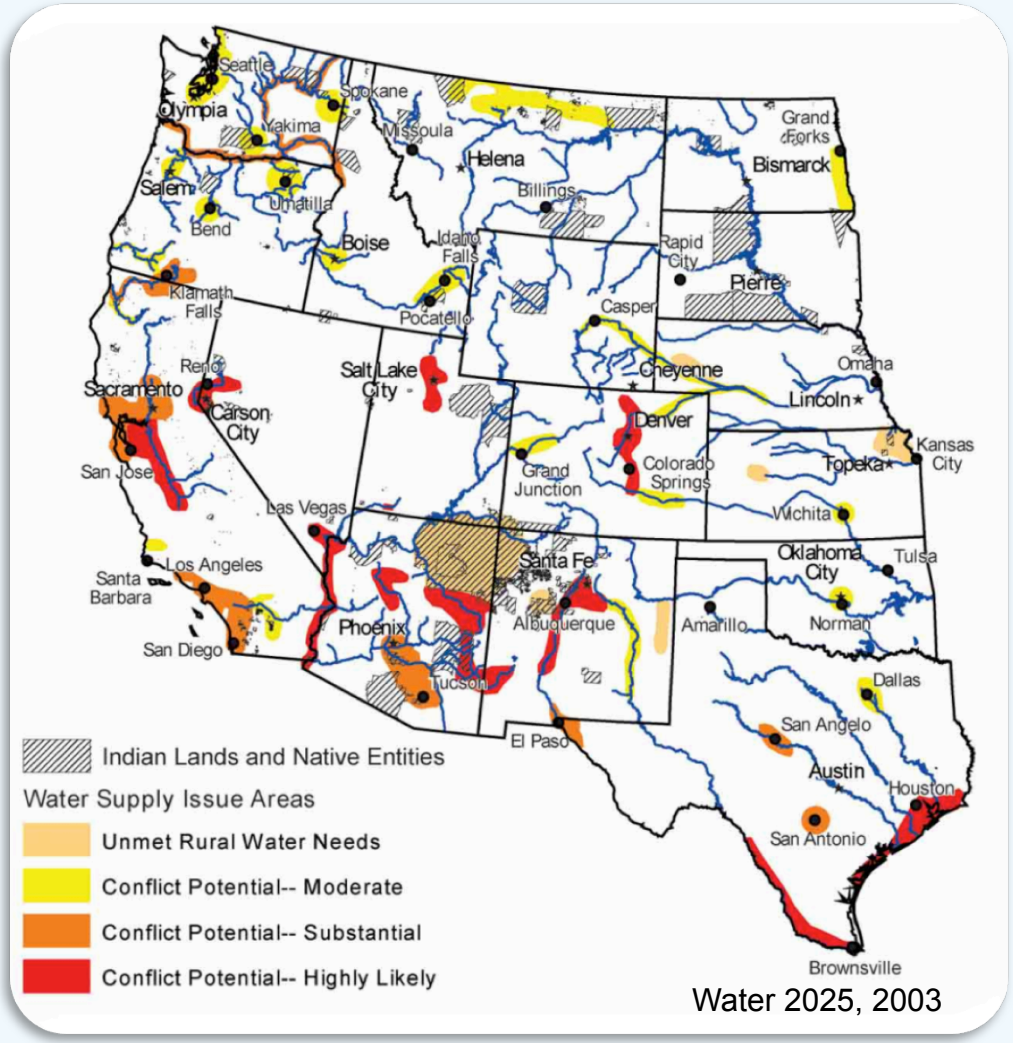
Regional Challenges

- **Rapidly growing population**
- Social & environmental stresses
- Highly variable and complex climate



Regional Challenges

- Rapidly growing population
- **Social & environmental stresses**
- Highly variable and complex climate



Regional Challenges

- Rapidly growing population
- Social & environmental stresses
- **Highly variable and complex climate**

Cognitive Challenges

Source: CCSP SAP 5.1 2009

Within the water resources engineering community, the **stationarity assumption** is a fundamental element of professional training

POLICYFORUM

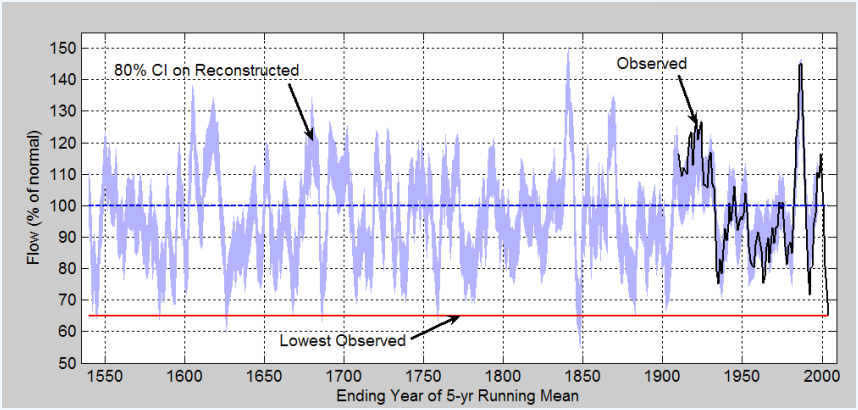
CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

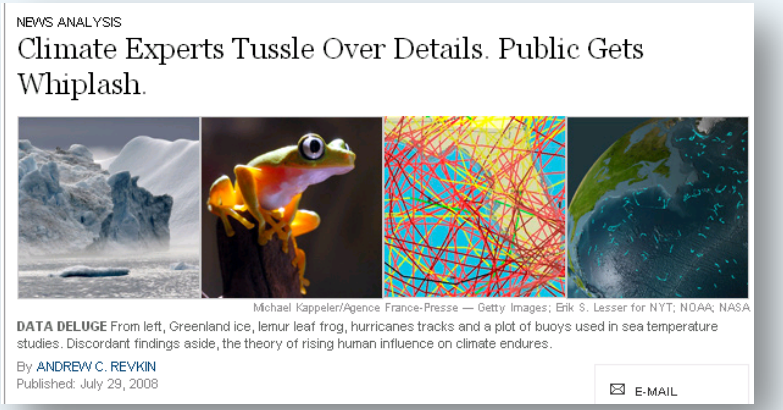
P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Milly et al. 2007



Meko et al. 2007

Time scales of climate change exceed typical planning and infrastructure design horizons and are remote from human experience



NEWS ANALYSIS

Climate Experts Tussle Over Details. Public Gets Whiplash.

Michael Kappeler/Agence France-Presse — Getty Images; Erik S. Lesser for NYT; NOAA; NASA

DATA DELUGE From left, Greenland ice, lemur leaf frog, hurricanes tracks and a plot of buoys used in sea temperature studies. Discordant findings aside, the theory of rising human influence on climate endures.

By ANDREW C. REVKIN

Published: July 29, 2008

E-MAIL

Confusion in conceptually melding **the burgeoning climate change impacts literature**

WWA Team

- **Core Office**
- **Research Team**
- Advisory Board

Colorado
University of Colorado at Boulder

CIRES

NOAA

UtahStateUniversity

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Alexander, Michael
Scientist, NOAA ESRL Physical Sciences Division
Climate Extremes

Bates, Gary
Research Associate, CIRES, Univ. of Colorado
Climate Modeling

Doesken, Nolan
Colorado State Climatologist, CSU
Climatology

Goemans, Chris
Assistant Professor, Agricultural and Resource Economics, CSU
Water Resource Economics

Hoerling, Martin
Scientist, NOAA ESRL Physical Sciences Division
Climate Variability, Hydrology

Klein, Roberta
Managing Director of CSTPR, Univ. of Colorado
Environmental Policy

Neff, Jason
Associate Professor, Geological Sciences & Environmental Studies, Univ. of Colorado
Biogeochemistry

Painter, Thomas
Assistant Professor, Geography, Univ. of Utah
Hydrology

Ray, Andrea
Scientist, Climate Analysis Branch, NOAA ESRL Physical Sciences Division
Climate-Society Interactions, Water Management

Travis, William
Associate Professor, Geography; Director, CSTPR, Univ. of Colorado
Natural hazards; climate impacts and adaptation

Averyt, Kristen
Deputy Director, Western Water Assessment
Climatology, Assessment Processes

Burke, Indy
Director, Haub School & Ruckelshaus Institute, Univ. of Wyoming
Ecology, Renewable Resources

Eischeid, Jon
Research Associate, CIRES, Univ. of Colorado
Climate Modeling

Getches, David
Dean, Univ. of Colorado Law School
Natural Resources Law

Gordon, Eric
PhD Student, Univ. of Colorado
Climate Adaptation

Jackson, Steve
Professor, Botany, Univ. of Wyoming
Ecology

Lukas, Jeffrey
Senior Research Associate, Western Water Assessment
Paleohydrology, Forest Ecology

Neff, William
Director, PSD, NOAA ESRL
Atmospheric Physics

Squillace, Mark
Director, NRLC, Univ. of Colorado
Natural Resources Law

Udall, Bradley
Director, Western Water Assessment
Colorado River, Hydrology, Policy

Wolter, Klaus
Research Associate, CIRES, Univ. of Colorado
Climatology

Webb, Robert S
Chief, Climate Analysis Branch, NOAA ESRL Physical Sciences Division
Paleoclimatology

Barsugli, Joseph
Research Associate, CIRES, Univ. of Colorado
Climate Dynamics

Jeffrey Deems
Research Associate, CIRES, Univ. of Colorado
Climate and Snow Modeling

Dilling, Lisa
Assistant Professor, Environmental Studies, Univ. of Colorado
Climate Info. and Decision-Making

Gillies, Robert
Utah State Climatologist, Utah State Univ.
Climatology

Gray, Stephen
Wyoming State Climatologist, Univ. of Wyoming
Climatology and Paleoclimatology

Kenney, Douglas
Director, Western Water Policy Program, NRLC, Univ. of Colorado
Western Water Policy and Law

McCutchan, James
Deputy Director, Center for Limnology, CIRES, Univ. of Colorado
Limnology

Nowak, Kenneth
PhD Student, CADSWES, Univ. of Colorado
Hydrology

Rajagopalan, Balaji
Associate Professor, Civil Engineering, Univ. of Colorado
Hydrology

Steffen, Konrad
Director, CIRES, Univ. of Colorado
Climatology

van Drunick, Suzanne
Assistant Director for Science, CIRES, Univ. of Colorado
Hydrology and Ecology

WWA Team

- Core Office
- Research Team
- **Advisory Board**

William Neff
Michelle Schmidt

James Verdin

Curtis Brown	Director, Research and Development, Reclamation Science and Technology
Terrance Fulp	Deputy Regional Director of the Bureau of Reclamation's Lower Colorado Region
Jennifer Gimbel	Director, Colorado Water Conservation Board
Melinda Kassen	Director, Western Water Project, Trout Unlimited
Eric Kuhn	General Manager, Colorado River Water Conservation District
Chuck Kutscher	Principal Engineer, National Renewable Energy Laboratory, Department of Energy
Patricia Mulroy	General Manager, Southern Nevada Water Authority
William Neff	Director, Physical Science Division, NOAA Earth System Research Laboratory
Michelle Schmidt	Hydrologist in Charge, NOAA Colorado Basin River Forecast Center
Robert Wigington	Western Water Policy Counsel, The Nature Conservancy
James Verdin	Deputy Director, National Integrated Drought Information System (NIDIS), USGS

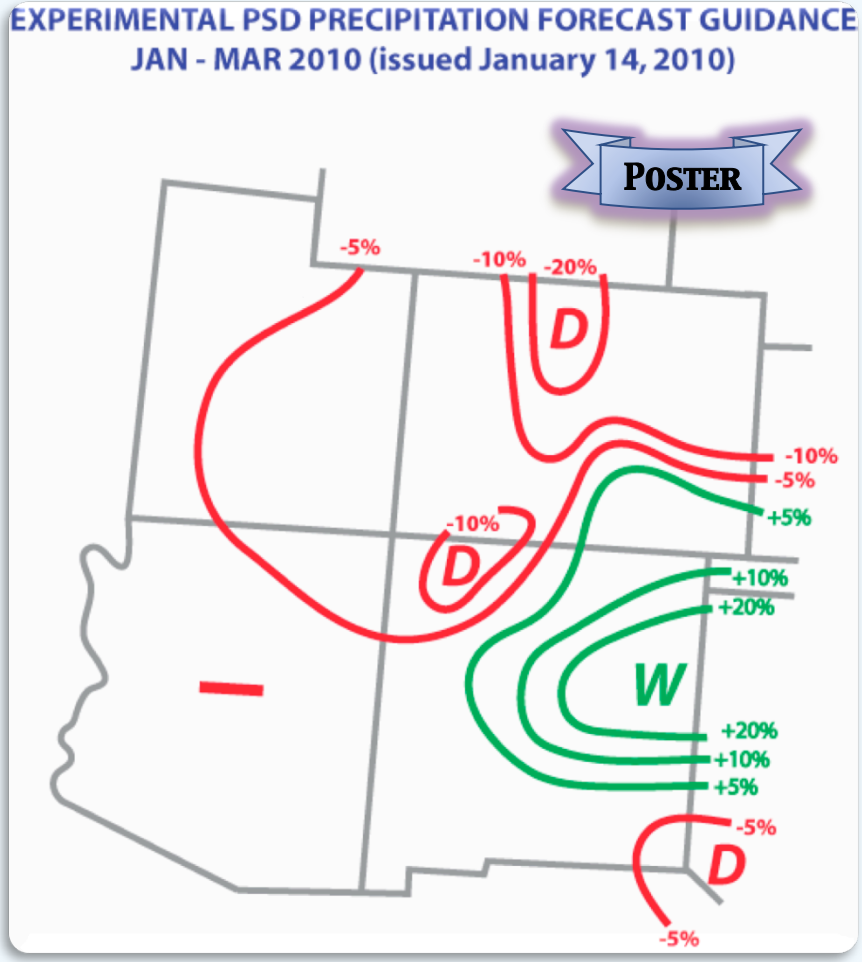
Past Successes

- **Intermountain West Climate Summary**
  (PSD: Lukas, Alvord, Averyt, Wolter, Ray, Bates)
- Experimental SW Forecasts (PSD: Wolter)
- Appendix U (PSD: Udall)
- Climate Change in Colorado Report
  (PSD: Ray, Barsugli, Averyt, Wolter, Hoerling, Udall, Webb)

wwa.colorado.edu/IWCS/index.html

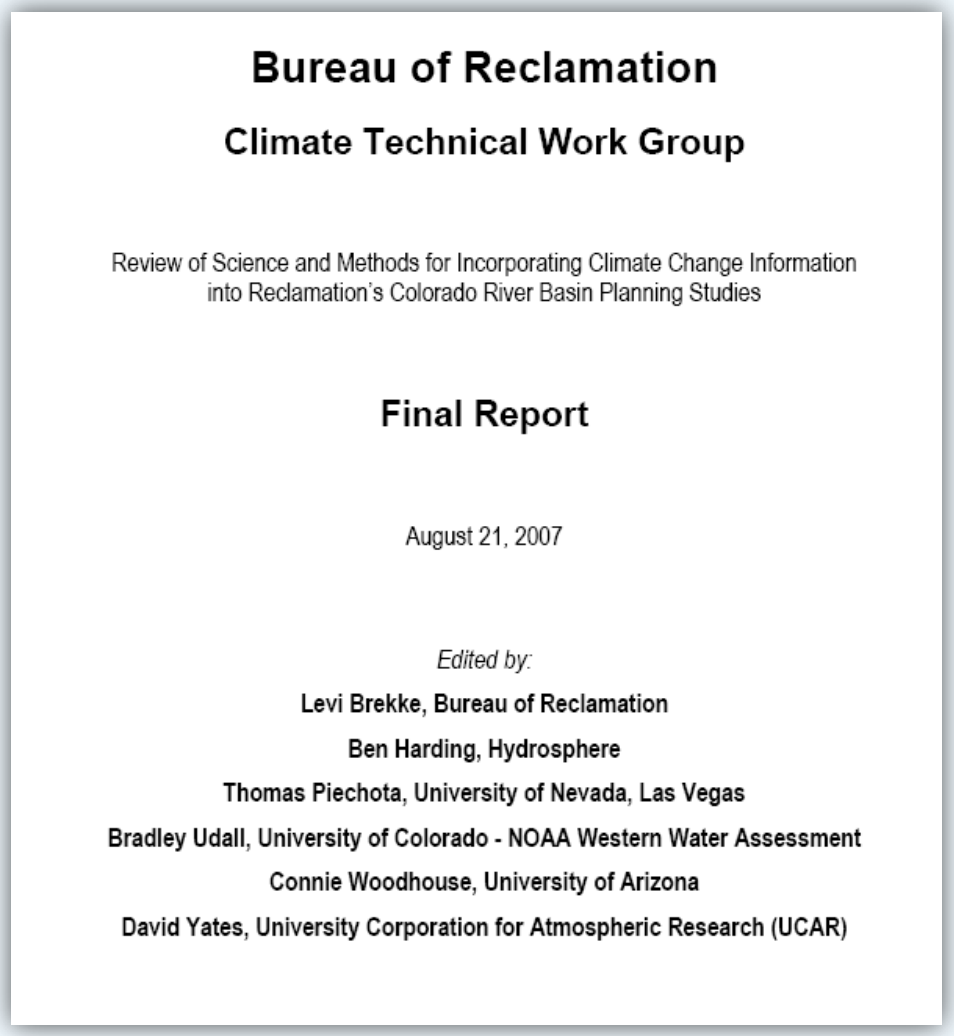
Past Successes

- Intermountain West Climate Summary
  (PSD: Lukas, Alvord, Averyt, Wolter, Ray, Bates)
- **Experimental SW Forecasts (PSD: Wolter)**
- Appendix U (PSD: Udall)
- Climate Change in Colorado Report
  (PSD: Ray, Barsugli, Averyt, Wolter, Hoerling, Udall, Webb)



Past Successes

- Intermountain West Climate Summary (PSD: Lukas, Alvord, Averyt, Wolter, Ray, Bates)
- Experimental SW Forecasts (PSD: Wolter)
- **Appendix U (PSD: Udall)**
- Climate Change in Colorado Report (PSD: Ray, Barsugli, Averyt, Wolter, Hoerling, Udall, Webb)



Bureau of Reclamation

Climate Technical Work Group

Review of Science and Methods for Incorporating Climate Change Information into Reclamation's Colorado River Basin Planning Studies

Final Report

August 21, 2007

Edited by:

Levi Brekke, Bureau of Reclamation

Ben Harding, Hydrosphere

Thomas Piechota, University of Nevada, Las Vegas

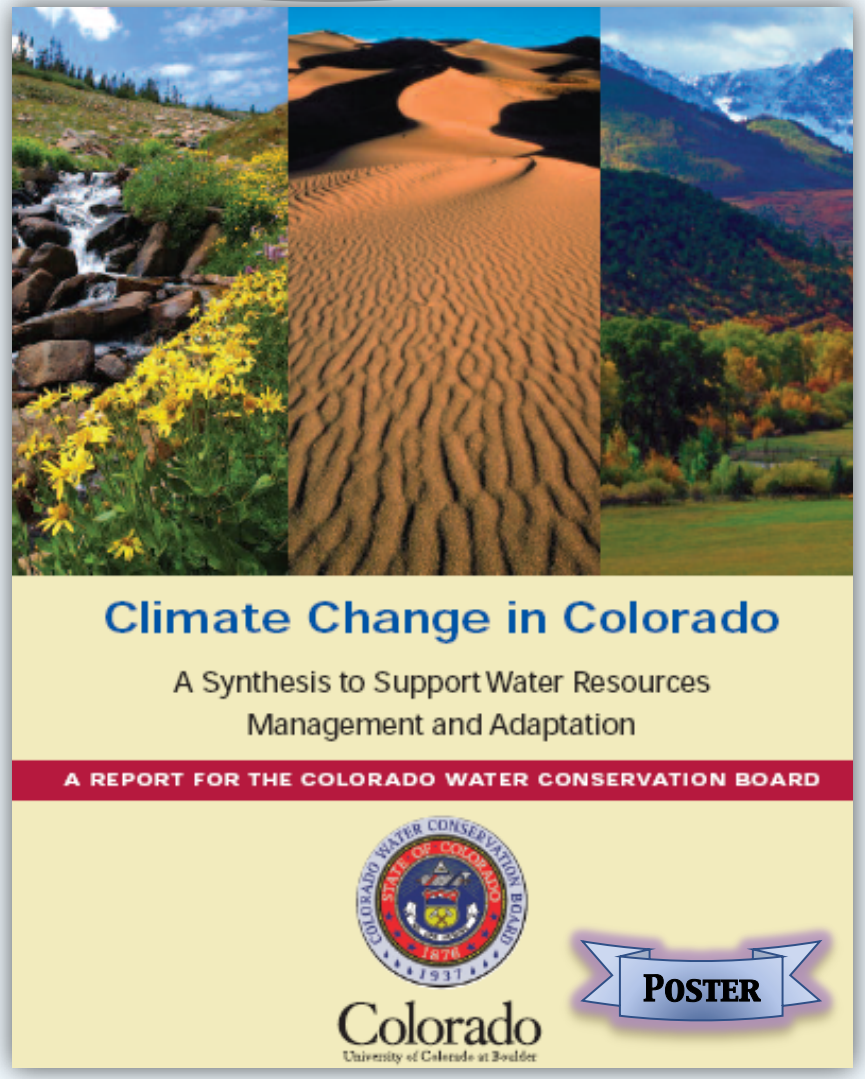
Bradley Udall, University of Colorado - NOAA Western Water Assessment

Connie Woodhouse, University of Arizona

David Yates, University Corporation for Atmospheric Research (UCAR)

Past Successes

- Intermountain West Climate Summary (PSD: Lukas, Alvord, Averyt, Wolter, Ray, Bates)
- Experimental SW Forecasts (PSD: Wolter)
- Appendix U (PSD: Udall)
- **Climate Change in Colorado Report (PSD: Ray, Barsugli, Averyt, Wolter, Hoerling, Udall, Webb)**



Current Projects

Decision Support for the Colorado River Basin & Headwaters

- **Dust on Snow**
- **Reconciling CO River Flows**
- **Utah Paleohydrology**
- CO River "24-month study"
- CO River Governance Initiative
- **Comparison of CO River and Australian drought management practices**

Ecosystem Services: Vulnerabilities, Impacts, & Adaptation

- **Pine Beetle Survey**
- Community Adaptations to Pine Beetles
- **Pesticides, Beetles, Water Quality and Fish**
- San Juan High Desert ecosystem climate vulnerability

Emerging Initiatives & Adaptation Strategies to Inform Climate Services

- **Energy-Water-Climate-Security Nexus**
- **Toolkit for Engaging Users in Climate Services**
- **CO Climate Workshops**

Bold indicates PSD-collaborative efforts

Reconciling Projections of CO River Flows

- Wide range of 2050 projections
- NOAA PSD, WWA, Scripps, U. Arizona, U. Washington, Reclamation

POSTER

TABLE 5-1. Projected Changes in Colorado River Basin Runoff or Streamflow in the Mid-21st

Study	GCMs (runs)	Spatial Scale	Temperature	Precip	Risk Estimate
Christensen et al. 2004	1 (3)	VIC model grid (~8 mi)	+3.1°F	-6%	Yes
Milly 2005, replotted by P.C.D. Milly	12 (24) (~100–300 mi)	GCM grids —	—		No
Hoerling and Eischeid 2006	18 (42)	NCDC Climate Division	+5.0°F	~0%	No
Christensen and Lettenmaier 2007	11 (22)	VIC model grid (~8 mi)	+4.5°F (+1.8 to +5.0)	-1% (-21%	Yes
Seager et al. 2007*	19 (49)	GCM grids (~100–300 mi)	—	—	No
McCabe and Wolock 2008	—	USGS HUC8 units (~25–65 mi)	Assumed +3.6°F	0%	Yes
Barnett and Pierce 2008*	—	—	—	—	% Yes

Studies

Runoff (Flow)
-18%
-10 to -20% 96% model agreement
-45%
-6% (-40% to +18%)
-16% (-8% to -25%)
-17 %
Assumed -10% to -30%

(PSD: Webb, Udall, Hoerling, Eischeid, Barsugli)

rt 2008

Reconciling Projections of CO River Flows

- Wide range of 2050 projections
- NOAA PSD, WWA, Scripps, U. Arizona, U. Washington, Reclamation

POSTER

ISSUES

- Topography & resolution matter
- Physical processes are not well observed or represented in models
- Communication matters

TABLE 5-1. Projected Changes in Colorado River Basin Runoff or Streamflow in the Mid-21st Century from Recent Studies

Study	*GCMs (runs)*	*Spatial Scale*	*Temperature*	*Precipitation*	*Year*	*Runoff (Flow)*	*Risk Estimate*
Christensen et al. 2004	1 (3)	VIC model grid (~8 mi)	+3.1°F	-6%	2040–69	-18%	Yes
Milly 2005, replotted by P.C.D. Milly	12 (24) (~100–300 mi)	GCM grids —	—		2041–60	-10 to -20% 96% model agreement	No
Hoerling and Eischeid 2006	18 (42)	NCDC Climate Division	+5.0°F	~0%	2035–60	-45%	No
Christensen and Lettenmaier 2007	11 (22)	VIC model grid (~8 mi)	+4.5°F (+1.8 to +5.0)	-1% (-21% to +13%)	2040–69	-6% (-40% to +18%)	Yes
Seager et al. 2007*	19 (49)	GCM grids (~100–300 mi)	—	—	2050	-16% (-8% to -25%)	No
McCabe and Wolock 2008	—	USGS HUC8 units (~25–65 mi)	Assumed +3.6°F	0%	—	-17 %	Yes
Barnett and Pierce 2008*	—	—	—	—	2057	Assumed -10% to -30%	Yes

(PSD: Webb, Udall, Hoerling, Eischeid, Barsugli)

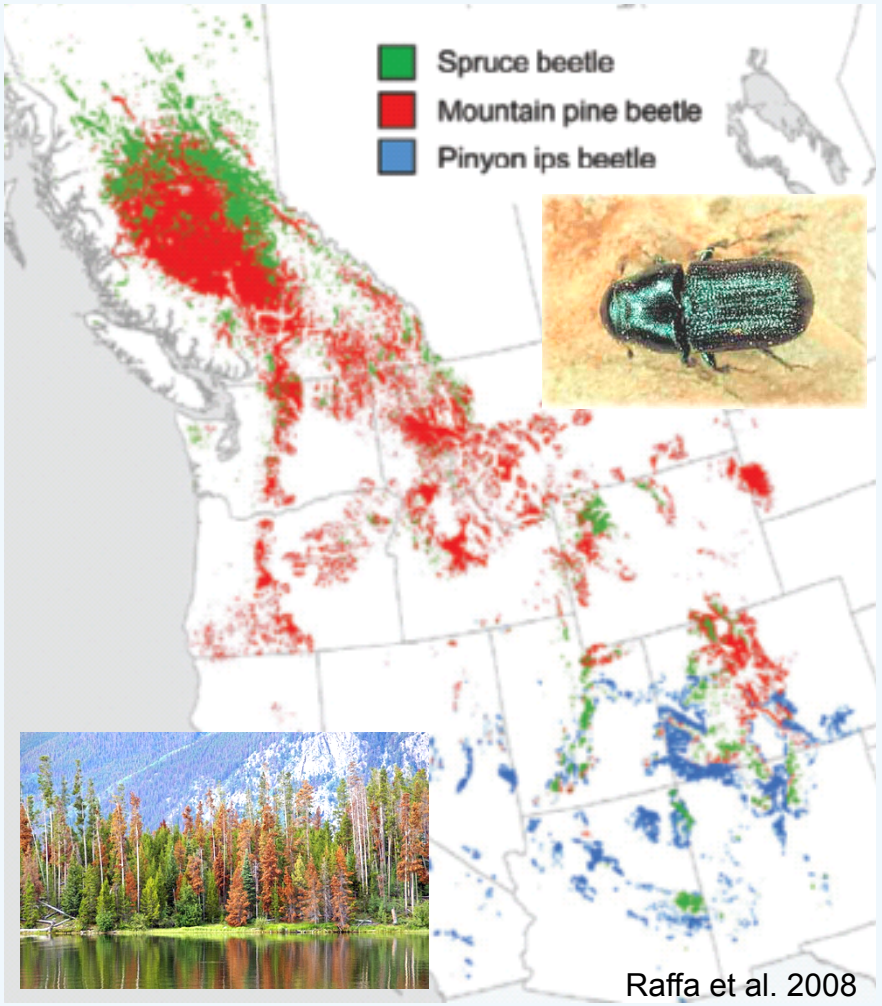
Source: CO Climate Report 2008

Bark Beetles:
Adding the Ecosystem Dimension

CHALLENGES

Multi-stressors

- Temperature
- Moisture
- Hydrologic Cycle
- Wildfire
- Forest Management
- Water Quality



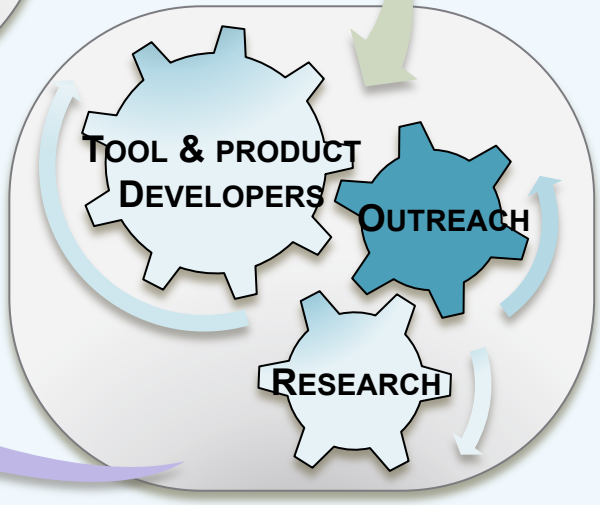
(PSD: Lukas, Gordon)

Engaging Users in Climate Services

Users & Existing Climate Information

Climate Services Machine

Better Climate Information & Informed Users



Informed Users & Better Climate Information

PROTOPTYPING EFFORTS:

- Colorado Water Conservation Board
- USFS
- NOAA NWS RFC

(PSD: Averyt, Lukas, Alvord)

Questions?